Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

PETROLOGICAL ABSTRACTS AND REVIEWS

LOEWINSON-LESSING, FRANZ. "The Fundamental Problems of Petrogenesis, or the Origin of Igneous Rocks," *Geol. Mag.*, N.S., Dec. V, VIII (1911), 248–57, 289–97.

HARKER, ALFRED. "Some Aspects of Modern Petrology," Vice-presidential address before Section C of the British Assoc. Adv. Sci., Portsmouth, 1911. Pp. 12.

IDDINGS, JOSEPH P. "Problems in Petrology," *Proc. Amer. Phil. Soc.*, L (1911), 286–300.

CROSS, WHITMAN. "The Natural Classification of Igneous Rocks," *Quar. Jour. Geol. Soc.* (of London), LXVI (1910), 470–506.

Discussion of the great problems of igneous rocks is a necessary forerunner of any unanimity of belief concerning them, such as must exist before the science of petrology can claim to have advanced beyond the formulative stages. In the papers here under review many of these problems are freely discussed from different standpoints. An outline of their scope and character may serve to show the present condition of the science of petrology.

The problems of petrogenesis discussed by Loewinson-Lessing are indeed fundamental, some of them reaching so far back into the earth's history or dealing with phenomena of such depths in its mass that few petrologists speak with confidence of their solution upon our present meager basis of established fact. The author of the essay under review is one of those who do speak with an assurance for which there is scant justification in the considerations presented, or, indeed, in the knowledge of today. Yet such discussions are of undoubted interest and value in more ways than one.

Loewinson-Lessing believes in two primordial magmas which he calls granitic and gabbroidal. He advocates, as he acknowledges, the ideas of Bunsen and Michel-Lévy in modified form. It is sought to establish the primordial nature of these two magmas by discussing the average composition of the earth's crust. The known variations exhibited by igneous rocks are ascribed to differentiation, assimilation, and, in apparently subordinate degree, to mixture of the two original magmas.

In discussion of "the average chemical composition of the earth's crust and the primordial magma" Loewinson-Lessing criticizes the results reached by Clarke and Washington and others as obtained by incorrect methods, but accepts their averages as accidentally nearly correct since they agree well with the mean of certain average compositions for granite and gabbro obtained by Daly. These latter averages seem to be accepted by Loewinson-Lessing as representing his primordial magmas in preference to any figures of his own, but they too must have been obtained by the methods esteemed faulty, and when one considers the different analyses various men would use in securing averages of "granite" or "gabbro," or any other rock type or group, one almost wonders where the value of such compilations comes in. If the author's conception of granite or gabbro is as peculiar as that announced for "syenite" one may well look askance at averages of his compilation. He says the mean of Daly's granite and gabbro "corresponds almost exactly to the syenitic magma." This mean carries 4.40 per cent MgO and 6.66 per cent CaO. A rock of this composition falls in subrange tonalose (II.4.3.4) and its norm contains 24.2 per cent anorthite and 11.9 per cent of quartz!

It is clear to Loewinson-Lessing that this "syenitic" mean represents two primordial magmas rather than one. This thesis is supported chiefly by dogmatic assertion. There is not much to convince the reader, for example, in his assertion that the "syenitic" magma could not be the original one "because the syenite is itself a derived magma." Nor is it any more conclusive that the primitive monzonitic and essexitic magmas of Rosenbusch cannot be so regarded "because the monzonites are one of the products of the largely differentiated gabbro-syenitic magmas, but are not sensibly subject to differentiation." Rosenbusch apparently does not know this and possibly he may question the statement!

By equally cogent reasoning Loewinson-Lessing disposes of all other views as to primordial magmas and reaches four generalizations which may be concisely stated as follows: (1) There were two primordial earth magmas, of granitic and gabbroidal composition. (2) "The different members of the granite formation and the gabbro-pyroxenitic-peridotitic formation occur in much larger bodies and have a far greater development than other eruptives," which is considered evidence of their primitive character. (3) The primordial nature of granitic and gabbroidal magmas is shown by abundance of facies and of associated differentiation products, which cannot be equally prominent with the intermediate magmas because they are themselves differentiation products. (4) "The original independence of the granitic and the gabbro-noritic formations" is indicated by the absence of such transitional types as would speak for the production of one from the other through differentiation.

The second problem of petrogenesis discussed is "the causes of the diversity of igneous rocks." The processes invoked are differentiation and assimilation. The author does not seem to realize that we are just beginning to acquire the data needed for an understanding of the actual chemical and physical processes involved in what he discusses so confidently. Eutectic magmas are spoken of as though well known. The process by which a non-eutectic magma may separate into its eutectic and various parts representing the dissolved substances is not considered. No creative suggestions like those characterizing Vogt's writings are found in this paper.

That assimilation of foreign matter has disturbed the natural course of differentiation to a great extent is Loewinson-Lessing's main contention. He cites a list of advocates of assimilation, but the main argument for it is contained in the question raised, "Is not assimilation a phenomenon that must be expected a priori in intrusive bodies, for it is difficult to imagine a magmatic basin heating the rocky masses in contact with it for a long period without partly dissolving them?" It is indeed necessary to recognize that where conditions of fusion exist that form of solution will take place, and further that where such conditions do not exist the fusion will not occur. Conditions we do not yet understand set limits for this process, not the range of a petrologist's imagination.

That many magmas represented in rocks open to investigation came from depths where the conditions of fusion and assimilation existed is seemingly incontestable. For magmas or rocks of such origin the course of differentiation producing them may have been decidedly interrupted and one can readily conceive of various plausible conditions greatly complicating the genetic problem. In this very situation lies the basis of the view, held by the present writer, that petrogenetic classification for all rocks must remain impracticable.

But the assumption that assimilation has taken place generally in large intrusive bodies at contacts now visible is not plain to many petrologists. Loewinson-Lessing's simple statement that "In an intrusive body of laccolithic type assimilation takes place in the manner of stoping as elucidated by Daly" illustrates the ease with which he accepts generalizations favorable to his theories. The origin of nepheline syenite from granitic magmas through the reactions connected with assimilation of limestone, as hypothecated by Daly, is also accepted by Loewinson-Lessing as assisting him out of a recognized dilemma.

"What origin have the igneous rocks and why are they represented by the same types in all periods?" is the third question discussed. Loewinson-Lessing believes in a fluid nucleus, that no trace of the primordial crust remains, that all magmas of rocks were derived by the fusion and refusion of the crust, principally from its lower surface. As the materials are always the same worked over and over again, the range of composition cannot change except that probably extreme products will become more abundant with time. Theory and speculation run persistently all through this discussion unbridled by too close connection with fact or formulated laws. The following quotation (p. 254) seems to indicate the author's point of view: "We take it as a *fact* that there must be admitted two independent primordial magmas, while all other eruptive rocks are derivates from them, originating by assimilation and differentiation. Such a *hypothesis* is based on the following facts and considerations." The italics, inserted by the reviewer, serve to illustrate the lack of distinction between fact, theory, hypothesis, and opinion prevailing in the discussion and markedly decreasing its value.

It is worthy of comment that Loewinson-Lessing does not go to the root of the matter by considering the origin of the "primordial" magmas assumed by him and their relation to the earth as a whole. Nor does he touch the great problems to which Harker gives his attention.

The special theme of Harker's address is "the geographical aspect of petrology," introduced by a review of the geographical distribution of igneous rocks. Then comes a discussion of "the alkaline and calcic branches" and of "the relation between tectonic and petrographical facies." The latter is illustrated by references to the relations existing in the north British Tertiary province, as worked out by Harker. The bearing of the considerations presented on petrogenesis and systematic petrography is taken up briefly in conclusion.

The aim in Harker's address, as in his valuable and interesting work on the *Natural History of Igneous Rocks*, is plainly to contribute to a logical interpretation of the known facts and relations of igneous rocks. This should be the ambition of every petrologist, yet in the succeeding comments on this address the reviewer's wish is to give point to his own belief, in which he is not alone, that some of the great generalizations accepted by Harker, and many with him, are not yet sufficiently in accord with the facts to serve the uses made of them. In the desire to elucidate, what is in its essence most complex and elusive, the experience of the ages with premature or hastily formulated hypotheses must not be forgotten.

As T. W. Richards has anew and most felicitously stated the principle which should guide us as petrologists, "The soundness of all important conclusions of mankind depends on the definiteness of the data on which they are based. . . . . The more subtle and complicated the conclusions to be drawn, the more exactly quantitative must be the knowledge of the facts."[1]

It may be well to anticipate somewhat by noting that the generalizations particularly questioned by the present writer are the existence of the alkaline and calcic branches of igneous rocks and the correctness of various forms of statement concerning their distribution on the earth, their genetic and tectonic relations. The first-named and most popular conception rests almost wholly on the strongly marked and contrasting characters of certain very different series or families of rocks. It has never been justified by thorough and unbiased study of the host of intermediate series.

In the discussion of geographic distribution Harker first refers to the commonly accepted generalization of petrographic provinces. Few, if any, petrologists question the fact of the petrographic province. But few provinces have thus far been so thoroughly investigated that we know the full range of rocks occurring in them, their composition, and occurrence. The best known provinces are ones of strongly marked characters, as a rule.

The main theme of the address is, however, not the limited problem of the petrographic province but rather that of the two great hypothetical branches of igneous rocks variously called Atlantic and Pacific, alkali and subalkali, alkalic and calcic, etc. In the "Natural History of Igneous Rocks" Harker used the first named terms but here substitutes "alkaline and calcic." This division is referred to as "now becoming recognized as the most fundamental distinction to be made among igneous rocks" and our author's principal topic is, in fact, the broad relationship of these branches to the nature of tectonic movements in the earth's crust and the genetic significance of this relationship.

Such an address is not the place for details of fact, yet the layman and general geologist listening to this discussion must have been misled by the positive form of several generalizations made by Harker. Some of these are qualified, it is true, but so grudgingly and inadequately as to minimize the effect.

While no one has yet attempted a thorough and fair definition of the alkaline and calcic branches, Harker refers to their characters as "too well known to need recapitulation." The arbitrariness of referring a host of rocks of intermediate composition to one or the other of these undefined classes is not acknowledged. Exceptions are called "anomalies" and treated as of no moment. It is said that "A given province is either of calcic or of alkaline facies, typical members of the two branches not being found together." This may be true if a province is not a province when it has mixed characters. Again, it is said that "it is possible to map out the active parts of the earth's crust into great continuous regions of alkaline rocks on the one hand and of calcic rocks on the other." That may be true if numerous "anomalies" are disregarded and given a free hand in mapping through absence of criteria really distinguishing the branches.

---

[1] Faraday lecture, *Science*, XXXIV (1911), 538.

The interesting generalization most dwelt upon by Harker is expressed in these words, "The distribution of different kinds of rocks is seen to stand in unmistakable relation to the leading tectonic features of the globe." As here stated most petrologists of experience may agree with the author, for he merely says "different kinds of rocks" and does not specify the relation. In truth all the essential elements of this relation are still to be determined by careful study of many districts. When Harker jumps to the further conclusion that the significant relation is between the two branches of magmas and the different kinds of stresses producing folding or faulting of the crust, he goes far into the realm of hypothesis. That his devotion to this hypothesis leads him into apparently forced interpretation of admitted facts seems abundantly illustrated by his own sketch of the relations of the alkaline and calcic branches in the north British Tertiary province.

In this area of various epochs of eruption Harker is confronted with the necessity of explaining a provincial mingling of alkaline and calcic rocks. This is accomplished to his own satisfaction by postulating changes in the fundamental character of underlying magmas in harmony with the tectonic history, faulting having predominated in certain epochs in which alkaline rocks are thought to play the active rôle, while folding at other times is accompanied by the appearance of the calcic lavas.

The difficulties of this situation are numerous in any case. Basalts of puzzling associations are placed in the alkaline branch because of sodic zeolites which are thankfully recognized as really primary and a most important part of the magma, since through them the alkaline nature of the basalts can be determined. (This idea, if correct, may be conveniently applied to determine the primary or secondary origin of alkalic zeolites. In a basalt of a calcic series of lavas such zeolites ar necessarily to be regarded as formed by solutions bringing soda from a foreign source.)

Harker finds some rhyolites "without very distinctive characters" but the association with trachytes settles, for him, the question of their reference to the alkaline branch. This doubt must have been caused by lime, which is an "anomaly" in an alkaline rhyolite. Certain widespread basic sills "have little that is indicative of alkaline affinities," but they are associated with some porphyritic dolerites of more sodic character, and these are elsewhere associated with more "typical alkaline rocks," so the akaline nature of the first mentioned sills is considered established. Harker does not seem to realize that his argument also connects "typical alkaline rocks" with others of calcic character in a manner to illustrate the fact of transition from alkaline to calcic magmas.

He refers to "augite-andesites which taken by themselves must be assigned to the calcic division" but these "aberrant types" are regarded as products of a "subsidiary differentiation" which is apparently able to transgress the laws of ordinary differentiation.

The cases just cited, and others like them, seem to justify the suspicion that perhaps the north British Tertiary province illustrates the existence of intermediate parent magmas whose derivates through differentiation naturally tend in one direction to exhibit alkaline affinities or even "typical" characters, and in the other the more calcic varieties. Why is this not a natural result from differentiation of intermediate magmas?

The closing section of Harker's address, on "Petrogenesis and Systematic Petrography" is a plea for a genetic classification of igneous rocks. As in such arguments generally the necessity for many classifications of these objects of tremendously complex relations and history is ignored. The essential difference of the one systematic classification upon which our nomenclature must rest, *the* system of petrography, from other classifications of petrology is also ignored. The best illustration of this limited view of the situation is given by Harker's reference to the present writer's remark that "only generalizations without known exceptions in experience can be applied to the construction of a system that may be called natural," to which Harker seems to think his own attitude is antagonistic, namely, "I hold, on the contrary, that such a science as geology can be advanced only by the inductive method, which implies provisional hypotheses and successive approximations to the truth." The first opinion was expressed with regard to petrographic system only. The chief desideratum in a stable, non-theoretical, petrographic system is not the facility of naming a rock (important as this is) but the freedom such a condition would give to the broader and often conflicting generalizations of petrologists and geologists concerning the various deep-lying relations of igneous and other rocks. Picture the future of *systematic petrography* if based on "provisional hypotheses" and "successive approximations to the truth"!

The critical reader of this address cannot fail to be impressed at the opening and again at the close of the discussion by an inconsequence in the use of the terms petrology and petrography which has its counterpart in other places and leads to doubt as to the logic of the reasoning in certain important particulars. The distinction between petrology as the broad philosophical science of rocks, and petrography, as the descriptive or systematic part of petrology, is well-nigh universal today. This usage is both approved and violated by Harker. In his introductory remarks he acknowledges that the idea as to the limitations of *petrography* "correctly denotes its purely descriptive nature" and yet asserts that "*petrology* is at the present time in a state of transition . . . . from a merely descriptive to an inductive science. . . . ." Has the work of Bunsen, Durocher, Rosenbusch, and Brögger—not to mention many others—been "merely descriptive"?

Again, in his summary, Harker deplores the attitude of those who would abandon efforts to place *petrography* upon a genetic basis, which would be to renounce its claims as "a rational science," while he, in contrast, takes "a more hopeful view of the future of *petrology*"*!* There are many petrologists who hold the former view and yet join enthusiastically with Harker in the latter outlook, having regard for the distinction which he at times seems to lose sight of.

The discussion of the "Problems in Petrology" by Iddings is different from those of Harker and Loewinson-Lessing in that it is a statement of the problems of today, the ones which present knowledge makes most profitable for the labors of petrographer and petrologist, rather than of the ultimate questions, or even those dependent on provisional generalizations. It is the problems of the rocks themselves and those to be formulated from the closer study of petrographical provinces which Iddings specially considers, though the results are of interest also through their bearing on still more remote and fundamental relations.

The "actual mineral composition of igneous rocks" is first taken up as "a great field of research, imperfectly cultivated, capable of yielding immediate returns of the first importance for the solution of other problems connected with the mineral composition of these rocks." The study of texture is urged, as it "is a very definite exponent of physical conditions that attended the crystallization of each igneous magma." The accurate determination of the minerals of rocks as to quantity and composition is declared essential to a comprehension of the problems of igneous rock formation which are specified. The relation of mineral to chemical composition and conditions of crystallization is given as one of the pressing questions, with two particular phases: (1) the apparent absence of molecules called *occult* which the bulk analysis would indicate must be present in certain rocks; (2) the various modes possible in magmas of the same composition. The occult molecules are those held by recognized minerals in solid solution. Notable illustrations of these conditions are given and the difficulty of correlating rocks solely on mineral composition is pointed out.

It is shown that the elucidation of the laws controlling the production of mineral compounds from molten magmas is a problem for joint attack by petrographer, chemist, and geophysicist.

Under the heading "The Mathematics of the Petrology of Igneous Rocks" Iddings develops the view that magmas and the mineral aggregates resulting from their crystallization must be interpreted in terms of stoichiometric chemistry and quantitative physics: that igneous rocks constitute a series which is unbroken in itself; and that the division of such a series into parts for systematic or descriptive purposes is naturally, because inevitably, by some arbitrary choice of units. The rock "type" is declared to be "subjective, inherent in the petrographer, not the rock."

The abstract quantitative or mathematic relations of the basic properties of igneous rocks are dwelt upon to show a fundamental difference between them and organisms. Iddings deprecates, therefore, the form given the idea of Harker that we may come to a genetic or natural classification of igneous rocks based on some "fundamental principle analogous with that of descent, which lies at the root of classification in the organic world." The terms "consanguinity," "parent magma," "family," and others are expressive but should not lead to biological analogies, for we are dealing, not with organisms, capable of reproduction, but with "a series of chemical solutions and their solidified phases," although they "may be related to one another by reason of differential diffusion or fractional crystallization.

Other problems of igneous rocks are discussed by Iddings under the head of "Petrographical Provinces." Although himself one of the first to recognize and support the generalization outlined by Judd he acknowledges that as yet "little or no attempt has been made to define more precisely what constitutes the characteristics of any so-called petrographical province." "Nothing approaching completeness of definition, either as to composition of the rocks, or extent and limit of the region of occurrence, has ever been attempted." Iddings does not believe that the major provinces or regions of the earth, thought by Becke, Harker, and others to be characterized by the "Atlantic and Pacific" or the "alkaline and calcic" branches, are entitled to recognition.

From Iddings' standpoint the problem before petrologists today, respecting geographic distribution, "is the investigation and exact definition of the districts and regions of igneous rocks in all parts of the world, with the purpose of obtaining the data with which to form definite conceptions of what have been termed petrographical provinces." Existing data make it clear to him "that there are many kinds of such groups of igneous eruptions and not two strongly contrasted series; that they blend into one another in composition; that the delineation of the regions, or provinces, may be pronounced in some instances and ill-defined in others."

In view of Iddings' opinion concerning the very incomplete data of igneous rocks themselves, their relations and distribution, it is natural to find him expressing the belief that major problems such as "the relation of the composition of igneous rocks of different parts of the earth to its isostacy"; "the relation between the kinds of magma erupted in a particular region and the dynamical events within the region"; and the question of original homogeneity or heterogeneity in the earth, must wait for their reasonable solution on the accumulation of a great amount of exact data, by petrographer, chemist, geophysicist, and geologist.

The article by the present writer on "the natural classification of igneous rocks," which antedates the other discussions here reviewed may be briefly referred to. In the first place, petrographers and petrologists are reminded that a classification of rocks may be called *natural* only when the factors used in its construction are really the facts or relations of nature. It is pointed out that the generalization's used in many attempted classifications were so erroneous or inaccurate as to make the result peculiarly unnatural. The special object of the discussion is a defense of the quantitative classification of igneous rocks from the criticism urged most forcibly by the advocates of natural classification that the quantitative method is unnatural and arbitrary.

The authors of the quantitative system were moved to its formulation by the belief that genetic relations and some of the characters of igneous rocks are not adapted to serve as bases of their systematic petrographic classification, i.e., the one system on which their scientific nomenclature rests. In this paper the availability of various factors is given renewed discussion. Under the heading "Factors of Chemical Composition," objection is made to the primary distinction of Atlantic and Pacific Kindred or the alkaline and calcic branches as inaccurate and vague. It is pointed out that if the differences of composition are partly due, respectively, to primeval variation, magmatic differentiation, and assimilation, three independent causes, the laws of differentiation alone cannot be applied to all rocks in a systematic way.

In considering the propositions emanating from Rosenbusch to use these laws in formulating the current system the distinction of two great magmatic series and the division of "dike rocks" are characterized as really unnatural. Instances of "dike rock" association and occurrence conflicting with the basal generalization are given.

Classification by eutectics is reviewed, with reference to the propositions of Becker and Vogt, and rejected, as inapplicable to all rocks, and based on a part of the rock at best. It is furthermore extremely hypothetical at the present time.

Factors of mineral and textural characters are next considered and the well-known fundamental objections to their systematic use are reviewed. The former is not only too complex for practical use but we now know that it is not, as once assumed, a simple function of chemical composition, but depends partly on variable and independent physical conditions.

The section of this paper dealing with the quantitative system is devoted to correcting certain misconceptions, to explaining that the norm is largely a means of expressing the molecules actually in magmatic solution and not a pure figment of the imagination, and to reviewing certain criticisms, particularly some expressed by Harker.

WHITMAN CROSS